Iowa Department of
Natural Resources

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Estimation of Greenhouse Gas Emissions

Methods for Select Stationary Sources

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Chapter 1: Introduction

Iowa Code 455B.131, as amended by Senate File 485 in 2007, requires the Iowa Department of Natural Resources (DNR) to include emissions estimates of greenhouse gases in its construction permitting and emissions inventory programs. This document provides guidance for estimating greenhouse gas emissions from select stationary sources. It is intended to reflect the most recent information on data sources, emission factors, and methods that are consistent with the *Intergovernmental Panel on Climate Change Good Practice Guidance,* the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, the California Climate Action Registry's *General Reporting Protocol,* and EPA guidance.

There are several different chemicals considered greenhouse gases. Iowa Code 455B.131 defines greenhouse gas as meaning:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFC's)
- Perfluorocarbons (PFC's)
- Sulfur hexafluoride (SF_6)

Emission estimate methods discussed in this document consider direct emissions only. It does not cover emissions from any indirect sources such as vehicle miles traveled, offsite waste disposal, or electricity consumption. Methods for estimating indirect greenhouse gas emissions may be added in the future.

This document does not mandate the use of specific emission factors, but only suggests appropriate emission factors and estimation methods. It is intended to be a living document which the DNR plans to periodically update to incorporate new or updated emission factors and methods as they become available.

To stay informed of important updates, please visit the Air Quality Bureau's webpage at www.iowacleanair.com and click on the 'Greenhouse Gas Emissions' icon. Additionally, you may wish to subscribe to the "IAirTech" list serve, which delivers regulatory news, program updates, and technical guidance directly to your email. To subscribe, send a blank E-mail to: join-iairtech@lists.ia.gov. The subject line should remain blank.

Chapter 2: Hierarchy of Emissions Estimation Methods

Emissions must be based on the best possible method and may vary between source categories. A general hierarchy of estimation methods is listed below in order of decreasing accuracy. Regardless of the method used to calculate emissions, supporting documentation that will allow DNR to recreate your emissions calculations should be included with any submission to the Department.

1. ***Continuous Emissions Monitoring (CEM)*** systems directly measure pollutant concentrations in the exhaust stack 24 hours a day. This is the most accurate method for determining emissions.

   Most likely used for: CO_2 emissions from utilities, ethanol plants, Portland cement plants, large combustion units, or other units with CEMs.

2. A ***Stack Test*** measures the concentration of pollutants in the exhaust stack during the test period. Test periods can vary from a couple of hours to an entire day. Stack test data can provide an accurate emission rate for many different processes and pollutants.

   Most likely used for: CO_2 emissions from combustion sources that have already been tested for particulate matter and other process-related CO_2 emissions from specific source categories.

3. ***Material Balance*** can only be used on specific types of emission units. Information must first be gathered on process rates, material used, and material properties (usually from ***material safety data sheets*** (MSDS). By combining this information with the knowledge of the process, an emission estimation can be made.

   Most likely used for: SF6, HFC, and PFC emissions.

4. ***Emission Factors*** are the basis for many calculations. Emission factors represent industry averages and show the relationship between emissions and a measure of production. Emission factors for select industries and processes, as well as reference sources for additional information, are provided in this document. When using an emission factor, you should use the most current version.

   Most likely used for: CO_2, CH_4, and N_2O emissions.

5. ***Vendor Supplied Factors*** may be used if a more preferred method is not available. This data may be used to calculate emissions only if the manufacturer's data is based on approved stack testing and no significant changes have been made to the emission unit.

6. ***Engineering Estimation*** is allowed if a more preferred method is not available. The DNR realizes that some processes have no published guidance regarding the estimation of emissions. In these cases, the estimation must be the best possible assessment given the amount of data available. Supporting documentation must be submitted to show how the estimation was made.

Chapter 3: Emissions Estimation Methods for Stationary Combustion Sources

CO_2, N_2O, and CH_4 are all emitted from the combustion of fuels from stationary sources. CO_2 is formed from the oxidation of the fuel carbon, CH_4 is a production of incomplete combustion, and N_2O is formed by oxygen-nitrogen reactions. If no CEM or stack test data is available, DNR suggests that emissions of these pollutants be calculated by multiplying the amount of fossil fuel combusted by the applicable emission factor(s) listed below in Tables 3.1 and Tables 3.2. The average adjusted emission factors listed below are from the California Climate Action Registry's *General Reporting Protocol, Version 2.2* and are also consistent with Intergovernmental Panel on Climate Change (IPCC) guidance.

Table 3.1: CO_2 Emission Factors for Stationary Fossil Fuel Combustion

Fuel	**CO_2 Emission Factor**
Residential coal	208.11 lbs./MMBtu
Commercial coal	208.11 lbs./MMBtu
Industrial coking coal	204.58 lbs./MMBtu
Industrial other coal	205.15 lbs./MMBtu
Utility coal	206.19 lbs./MMBtu
Natural gas	116.38 lbs./MMBtu
Distillate fuel (diesel)	159.69 lbs./MMBtu
Kerosene	157.86 lbs./MMBtu
LPG	136 lbs./MMBtu
Motor gasoline	154.79 lbs./MMBtu
Reformulated gasoline	153.75 lbs./MMBtu
Residual fuel	172.01 lbs./MMBtu
Propane	12.57 lbs./gal
Butane	14.38 lbs./gal
Methanol (neat)	9.06 lbs./gal
Crude oil	161.94 lbs./MMBtu
Still gas	140.86 lbs./MMBtu

Table 3.2: CH_4 and N_2O Emission Factors for Stationary Fossil Fuel Combustion

Fuel	**Sector**	**CH_4 Emission Factor**	**N_2O Emission Factor**
Coal	Industrial	0.0245 lbs./MMBtu	0.0035 lbs./MMBtu
	Commercial/Institutional	0.0245 lbs./MMBtu	0.0035 lbs./MMBtu
Petroleum	Industrial	0.0049 lbs./MMBtu	0.0015 lbs./MMBtu
	Commercial/Institutional	0.0245 lbs./MMBtu	0.0015 lbs./MMBtu
Natural gas	Industrial	0.0130 lbs./MMBtu	0.0002 lbs./MMBtu
	Commercial/Institutional	0.0130 lbs./MMBtu	0.0002 lbs./MMBtu
Wood	Industrial	0.0774 lbs./MMBtu	0.0104 lbs./MMBtu
	Commercial/Institutional	0.7748 lbs./MMBtu	0.0104 lbs./MMBtu
Distillate fuel	Industrial	0.00066 lbs./gal	0.00022 lbs./gal
	Commercial/Institutional	0.00309 lbs./gal	0.00022 lbs./gal

Table 3.2 (continued)

Fuel	Sector	CH_4 Emission Factor	N_2O Emission Factor
Kerosene	Industrial	0.00066 lbs./gal	0.00022 lbs./gal
	Commercial/Institutional	0.00309 lbs./gal	0.00022 lbs./gal
LPG	Industrial	0.00044 lbs./gal	0.00022 lbs./gal
	Commercial/Institutional	0.00221 lbs./gal	0.00022 lbs./gal
Residual fuel	Industrial	0.00066 lbs./gal	0.00022 lbs./gal
	Commercial/Institutional	0.00331 lbs./gal	0.00022 lbs./gal
Motor gasoline	Industrial	NA	NA
	Commercial/Institutional	0.00289 lbs./gal	0.00022 lbs./gal
Propane	Industrial	NA	NA
	Commercial/Institutional	NA	NA
Butane	Industrial	NA	NA
	Commercial/Institutional	NA	NA

<u>Example Calculations</u>

Assume that no CEM or stack test data is available.

1. Goal – calculate the CO_2, CH_4, and N_2O emissions from an industrial natural gas boiler that burned 26,250 MMBtu of natural gas (ngas) in a given year.

   CO_2 = 26,250 MMBtu ngas x 116.38 lbs. CO_2/MMBtu ngas x 1 ton CO_2/2000 lbs. CO_2
   = 1,527.49 ton CO_2

   CH_4 = 26,250 MMBtu ngas x 0.0130 lbs. CH_4/MMBtu ngas x 1 ton CH_4/2000 lbs. CH_4
   = 0.17 ton CH_4

   N_2O = 26,250 MMBtu ngas x 0.0002 lbs. N_2O/MMBtu ngas x 1 ton N_2O/2000 lbs. N_2O
   = 0.003 ton N_2O

2. Goal – calculate the CO_2, CH_4, and N_2O emissions from an utility coal boiler that burned 10,000,000 MMBtu of coal in a given year.

   CO_2 = 10,000,000 MMBtu coal x 206.19 lbs. CO_2/MMBtu coal x 1 ton CO_2/2000 lbs. CO_2
   = 1,030,950 ton CO_2

   CH_4 = 10,000,000 MMBtu coal x 0.0245 lbs. CH_4/MMBtu coal x 1 ton CH_4/2000 lbs. CH_4
   = 122.5 ton CH_4

   N_2O = 10,000,000 MMBtu coal x 0.0035 lbs. N_2O/MMBtu coal x 1 ton N_2O/2000 lbs. N_2O
   = 17.5 ton N_2O

3. Goal – calculate the CO_2, CH_4, and N_2O emissions from an industrial distillate oil generator that burned 50,000 gallons (7,000 MMBtu) of distillate fuel (DF) in a given year.

   CO_2 = 7,000 MMBtu DF x 159.69 lbs. CO_2/MMBtu DF x 1 ton CO_2/2000 lbs. CO_2
   = 558.92 ton CO_2

   CH_4 = 50,000 gallons DF x 0.00066 lbs. CH_4/ gallon DF x 1 ton CH_4/2000 lbs. CH_4
   = 0.0165 ton CH_4

   N_2O = 50,000 gallons DF x 0.00022 N_2O/ gallon DF x 1 ton N_2O/2000 lbs. N_2O
   = 0.0055 ton N_2O

Chapter 4: Emissions Estimation Methods for Select Industries

Greenhouse gases are also emitted from several stationary source categories (other than fossil fuel combustion) that may currently operate in Iowa. Table 4.1 below indicates with an 'x' which pollutant(s) are emitted by which source categories and also indicates the emission factor to be used (in absence of a higher-ranked emission method listed on page 5).

Table 4.1: Pollutants Emitted and Suggested Emission Factors for Select Industries

Source Type	**CO_2**	**Emission Factor Source**	**CH_4**	**Emission Factor Source**	**N_2O**	**Emission Factor Source**
Mineral Products						
Asphalt concrete	x	WebFIRE	x	WebFIRE		
Brick manufacture	x	WebFIRE	x	WebFIRE		
Cement production	x	WebFIRE				
Gypsum manufacture	x	WebFIRE				
Lime production	x	WebFIRE				
Limestone and dolomite use	x	see Table 4.2				
Soda ash consumption	x	see Table 4.3				
Chemical Industry						
Ammonia production	x	WebFIRE				
Nitric acid production					x	see Table 4.4
Metal Production						
Iron, steel, and ferroalloys	x	WebFIRE	x	WebFIRE		
Other						
In-process fuel use	x	see below	x	see below	x	see below
Ethanol production	x	see Table 4.5				
Pulp and paper	x	WebFIRE	x	WebFIRE		
Landfills	x	LandGem – see below	x	LandGem- see below		
Municipal solid waste combustion	x	see Table 4.6	x	see Table 4.6	x	see Table 4.6
Wastewater treatment	x	see below	x	see below	x	see below

Limestone use

Table 4.2: Suggested Emission Factors for Limestone and Dolomite Use

Process	Pollutant	Factor (metric)[1]	Factor (English)	Source of Factor
Limestone use	**CO_2**	0.12 metric tons/metric ton limestone	240 lbs/ton limestone	EIIP Volume 8 p. 6.4-11
Dolomite use	**CO_2**	0.132 metric ton/metric ton dolomite	264 lbs/ton dolomite	EIIP Volume 8 p. 6.4-11

[1] 1 ton = 0.9072 metric tons

Soda ash consumption

Table 4.3: Suggested Emission Factors for Consumption of Soda Ash

Process	Pollutant	Factor (metric)[1]	Factor (English)	Source of Factor
Consumption of soda ash	**CO_2**	0.415 metric ton/ metric ton soda ash consumed	830 lbs/ton soda ash consumed	EIIP Volume 8 p. 6.4-14

[1] 1 ton = 0.9072 metric tons

Nitric acid production

Table 4.4: Suggested Emission Factors for Nitric Acid Production

Process	Pollutant	N_2O Factor (metric)[1]	N_2O Factor (English)	Source of Factor
Nitric acid production with SCR	**N_2O**	0.0095 metric ton/ metric ton acid produced	19 lbs/ton acid produced	EIIP Volume 8 p. 6.4-16
Nitric acid production with NSCR	**N_2O**	0.002 metric ton/ metric ton acid produced	4 lbs/ton acid produced	EIIP Volume 8 p. 6.4-16
Nitric acid production with no known control	**N_2O**	0.008 metric ton/ metric ton acid produced	16 lbs/ton acid produced	EIIP Volume 8 p. 6.4-16

[1] 1 ton = 0.9072 metric tons

In-process fuel use

Use factors from Tables 3.1 and 3.2 of this document.

Ethanol production

Ethanol plants emit CO_2 from fermentation, drying, and in-process fuel use. CH_4 and N_2O are also emitted from in-process fuel use. Ethanol plants frequently have CEMs and have CO_2 stack test data. If not, emissions should be estimated as follows:

Table 4.5: Suggested Emission Factors for Ethanol Production

Source Type	Pollutant	Factor	Source of Factor
Drying & other in-process fuel use	CO_2, CH_4, N_2O	See Tables 3.1 and 3.2	California Climate Action Registry's *General Reporting Protocol, Version 2.2*
Fermentation	CO_2	67.74 lbs/1000gal	AP-42, Table 9.12.1-2 (Beer Production)

Landfills

CH_4 and CO_2 emissions from landfills should be calculated using EPA's Landfill Gas Emissions Model (LandGEM); see http://www.epa.gov/ttn/chief/efpac/efsoftware.html. Further guidance is being developed regarding the reporting of naturally occurring CH_4 and CO_2 emissions from organic matter.

Municipal Solid Waste Combustion

Combustion of municipal waste results in emissions of CO_2 and N_2O. As with landfills, guidance is being further developed regarding the reporting of naturally occurring CH_4 and CO_2 emissions from organic matter. Suggested emission factors include:

Table 4.6: Suggested Emission Factors for Municipal Solid Waste Combustion

Process	**Pollutant**	**Factor (metric)**	**Source of Factor**
CO_2 from plastics in MSW	**CO_2**	0.4048 ton/ton MSW	EIIP Volume 8 p. 13.4-14.
CO_2 from synthetic rubber in MSW	**CO_2**	0.0638 ton/ton MSW	EIIP Volume 8 p. 13.4-14.
CO_2 from synthetic fiber in MSW	**CO_2**	0.1258 ton/ton MSW	EIIP Volume 8 p. 13.4-14.
N_2O from MSW	**N_2O**	0.000044 ton/ton MSW	EIIP Volume 8 p. 13.4-14.

Wastewater treatment

This section is still under development.

Chapter 5: Emissions Estimation Methods for Hydrofluorocarbons (HFC), Perfluorocarbons (PFC), and Sulfur hexafluoride (SF_6)

Sources

Sources of HFCs, PFCs, and SF_6 in Iowa may include the following:

Table 5.1: Sources of HFC, PFC, and SF_6 Emissions in Iowa

Source Type	**HFC**	**PFC**	**SF_6**
Refrigerants & air conditioning systems	x	x	
Foam blowing	x		
Aerosols	x		
Fire suppression & explosion protection	x	x	
Solvent cleaning	x	x	
Electricity transmission & distribution[1]			x
Blanketing molten magnesium			x
Aluminum recycling			x
Thermal/sound insulation			x
Spare tires & airplane tires			x
Leak checking			x
High voltage insulation			x
Aluminum smelting		x	

[1] Over 80% of all SF_6 used world-wide is consumed by electricity transmission and distribution.

Estimation Method

HFC, PFC, and SF_6 are typically calculated using the following mass balance equation:

Emissions/year = (Base Inventory + Purchases/Acquisitions - Sales/Disbursements + Change to Total Full Charge of Equipment)

Example Calculation

Goal – calculate the HFC emissions from a 1000 ton Commercial Chiller using HFC-23.

Method – HFC emissions should be calculated by performing a mass balance calculation. The following data is needed to perform the calculation:

1. Types and quantities of air conditioning equipment
2. Total refrigerant discharge
3. Annual leak rates
4. Types of refrigerants
5. MSDS for refrigerants

Table 5.2: Example HFC-23 Mass Balance Calculation

	HFC-23 In Process (lbs)	**Running Total HFC (lbs)**
Beginning of year inventory	+ 1800	1800
End of year inventory	- 1780	20
Purchases (including HFC-23 provided by equipment manufacturer with or inside new equipment	+ 440	460
Amount returned to the site after offsite recycling	+ 0	460
Amount returned to supplier	- 0	460
Amount taken from storage and/or disposed of	- 0	460
Amount taken from storage and/or equipment and sent offsite for recycling or reclamation	- 120	340
Difference between total full charge of new equipment vs. total full charge of retiring equipment	+ 45	385
Total HFC-23 emissions		**385**

Acknowledgements

California Climate Action Registry. 2007. *Appendix to the General Reporting Protocol: Power/Utility Reporting Protocol, Reporting Entity-Wide Greenhouse Gas Emissions Produced by Electric Power Generators and Electric Utilities.* Internet address: http://www.climateregistry.org/PROTOCOLS.

California Climate Action Registry. 2007. *General Reporting Protocol, Version 2.2.* Internet address: http://www.climateregistry.org/PROTOCOLS.

IPCC/UNEP/OECD/IEA. 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories,* 3 volumes. Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Development, International Energy Agency. Paris, France. Internet address: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm.

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U.S. EPA. 2005. *Landfill Gas Emissions Model (LandGEM), version 3.02.* Internet address: http://www.epa.gov/ttn/chief/efpac/efsoftware.html.

U.S. EPA. 2005. *WebFIRE - Factor Information Retrieval (FIRE) Data System.* Internet address: http://cfpub.epa.gov/oarweb/index.cfm?action=fire.main.